

CLAIMS

What is claimed is:

1. A method of forming a semiconductor integrated circuit dielectric composite film, the method comprising:
 - 5 forming a dielectric matrix film on a semiconductor wafer; and distributing a reinforcing material comprising one of fibers and nanostructure whiskers throughout the dielectric matrix film to form the dielectric composite film.
 - 10 2. The method of forming a semiconductor integrated circuit dielectric composite film as recited in claim 1 wherein the reinforcing material comprises nanostructure whiskers.
 - 15 3. The method of forming a semiconductor integrated circuit dielectric composite film as recited in claim 1 wherein the dielectric matrix film is selected from the group consisting of SiO₂ and low-k dielectric layers.
 - 20 4. The method of forming a semiconductor integrated circuit dielectric composite film as recited in claim 1 wherein the reinforcing material is distributed simultaneously with the formation of the low-k dielectric matrix film using a CVD method.
 5. The method of forming a semiconductor integrated circuit dielectric composite film as recited in claim 1 wherein the reinforcing material comprises an insulating ceramic material.
 6. The method of forming a semiconductor integrated circuit dielectric composite film as recited in claim 2 wherein the whiskers are rod-shaped and have a length in the range from 5 to 20 nm.
 - 25 7. The method of forming a semiconductor integrated circuit dielectric composite film as recited in claim 2 wherein the whiskers have aspect ratios in the range of 5:1 to 300:1.

8. The method of forming a semiconductor integrated circuit dielectric composite film as recited in claim 2 wherein the whiskers are randomly oriented.

9. The method of forming a semiconductor integrated circuit dielectric composite film as recited in claim 2 wherein the volume of the whiskers in relation to
5 the volume of the matrix material lies in the range from 0.1 to 10 %.

10. The method of forming a semiconductor integrated circuit dielectric composite film as recited in claim 2 wherein the whiskers comprise one of SiC, Si₃N₄, and SiO₂, and diamond structured whiskers.

11. The method of forming a semiconductor integrated circuit dielectric
10 composite film as recited in claim 2 wherein the reinforcement whiskers are formed in the composite layer by suspending the whiskers in a spin-on liquid.

12. The method of forming a semiconductor integrated circuit dielectric composite film as recited in claim 1 further comprising heating the dielectric matrix film to vaporize volatile components.

15 13. The method of forming a semiconductor integrated circuit dielectric composite film as recited in claim 1 further comprising etching the dielectric matrix film to remove a majority of the dielectric film matrix.

20 14. The method of forming a semiconductor integrated circuit dielectric composite film as recited in claim 2 wherein the whiskers are single crystal nano-structures.

15. The method of forming a semiconductor integrated circuit dielectric composite film as recited in claim 2 wherein the whiskers have a bipolar structure and further comprising applying a field to the dielectric composite film to orient the whiskers in a predetermined orientation.

25 16. The method as recited in claim 1 further comprising forming an inlaid conductive layer in the low-k composite layer.

17. The method as recited in claim 16 wherein the inlaid copper layer is a copper dual-damascene interconnect structure.

18. A dielectric composite film comprising:
 - a low-k dielectric matrix film; and
 - whisker reinforcements distributed throughout the film.
19. The dielectric composite film as recited in claim 18 wherein the whisker reinforcements are selected from the group consisting of SiC, Si₃N₄, oxides, polymers, and diamond structured materials.
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20. The dielectric composite film as recited in claim 19 wherein the whisker reinforcements comprise an insulating ceramic.
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21. The dielectric composite film as recited in claim 19 wherein the whiskers occupy a volume in the matrix in the range of 0.1 to 10%.